

Departement Pferde  
der Vetsuisse-Fakultät Universität Zürich

Direktor: Prof. Dr. med. vet., Dr. h. c. Jörg Andreas Auer, MS, Diplomate ACVS,  
ECVS

**Comparison of the VetGate and SurgiGATE 1.0 Computer Assisted  
Surgery Systems for Insertion of Cortex Screws across the Distal  
Phalanx and Distal Sesamoid Bone in Horses: Two In Vitro Studies**

Inaugural-Dissertation

zur Erlangung der Doktorwürde der  
Vetsuisse-Fakultät Universität Zürich

vorgelegt von

**Cornelia Schwarz**

Tierärztin  
von Schaffhausen und Winterthur, Schweiz

genehmigt auf Antrag von

Prof. Dr. Jörg Andreas Auer, Referent

Prof. Dr. Lutz Nolte, Korreferent

Zürich 2010

To my beloved friends

## **Table of Contents**

<b>A. Summary</b>	<b>3</b>
<b>B. Introduction</b>	<b>4</b>
<b>C. Comparison of the VetGate and SurgiGATE 1.0 Computer Assisted Surgery Systems for Insertion of Cortex Screws across the Distal Phalanx in Horses: An In Vitro Study</b>	<b>5</b>
1. Introduction	6
2. Materials and Methods	7
3. Results	14
4. Discussion	16
5. Acknowledgment	18
6. References	18
<b>D. Introduction of 3.5mm and 4.5mm Cortex Screws into the Equine Distal Sesamoid Bone with the Help of the VetGate Computer Assisted Surgery System and Comparison of the Results with those Achieved with the SurgiGATE 1.0 System: An In Vitro Study</b>	
1. Introduction	22
2. Materials and Methods	23
3. Results	28
4. Discussion	34
5. Acknowledgment	35
6. References	35
<b>E. Acknowledgment</b>	<b>37</b>
<b>F. Curriculum Vitae</b>	<b>38</b>

## A. Summary

The goal of the first part was to evaluate the functionality and precision of the VetGate Computer Assisted Surgery (CAS) System during insertion of two 4.5mm cortex screws across imaginary midsagittal fractures of the distal phalanx (P3) in the horse and to compare the results with those achieved with the SurgiGATE 1.0 CAS-System. For this *in vitro* experimental study, five cadaveric equine limb pairs (n=10) were used. In every distal phalanx two 4.5mm cortex screws were inserted in lag fashion facilitated by the VetGate CAS-System.

The results achieved with the VetGate CAS-System are superior to the ones achieved with the SurgiGATE 1.0 System. The VetGate CAS-System allows exact screw placement at delicate locations.

In the second part, the functions and precisions of the VetGate Computer Assisted Surgery (CAS) System in imaginary midsagittal fractures of the equine distal sesamoid bone were evaluated. For this *in vitro* experimental study, ten cadaveric equine limb pairs (n=20) were used. A 3.5mm or 4.5mm cortex screw was inserted into each bone in lag fashion using CAS. The placement within the bone was perfect for all 20 screws. The results for the 3.5mm screws were perfect. The screw head of the 4.5mm screw damaged the articular surface in 8 out of 10 cases. A consolidated view indicates that standard 4.5mm screws are not feasible in Thoroughbreds and Warmblood horses of average size.

## B. Introduction

The goal of this work was the evaluation of the newly developed Computer Assisted Surgery (CAS) System *VetGate* and the comparison with the *SurgiGATE* 1.0 CAS-System.

The present work is divided into two parts. In the first part (Comparison of the *VetGate* and *SurgiGATE* 1.0 Computer Assisted Surgery Systems for Insertion of Cortex Screws across the Distal Phalanx in Horses; An In Vitro Study) the insertion of two cortex screws across an imaginary midsagittal distal phalanx fracture was compared with the results achieved by Andritzky et al.<sup>1</sup> with the antecedent *SurgiGATE* 1.0 CAS-System.

In the second part (Introduction of 3.5mm and 4.5mm Cortex Screws into the Equine Distal Sesamoid Bone with the Help of the *VetGate* Computer Assisted Surgery System and Comparison of the Results with those Achieved with the *SurgiGATE* 1.0 System: An In Vitro Study) one 3.5mm or 4.5mm screw was inserted along the long axis of the distal sesamoid bone (navicular bone) for the fixation of an imaginary midsagittal distal sesamoid bone fracture. The results were compared with those achieved by Gyax et al.<sup>2</sup>

1. Andritzky J, Rossol M, Lischer C, et al: Comparison of computer-assisted surgery with conventional technique for the treatment of axial distal phalanx fractures in horses: an in vitro study. *Vet Surg* 34:120-127, 2005
2. Gyax D, Lischer C, Auer JA: Computer-assisted surgery for screw insertion into the distal sesamoid bone in horses: an in vitro study. *Vet Surg* 35:626-633, 2006

**C. Comparison of the VetGate and SurgiGATE 1.0 Computer Assisted Surgery Systems for Insertion of Cortex Screws across the Distal Phalanx in Horses; An In Vitro Study**

**Cornelia S. Schwarz,** MedVet<sup>1</sup>, **Tobias Rudolph,** PhD<sup>2</sup>, **Jens H. Kowal,** ProfDr<sup>2</sup>,  
**Joerg A. Auer** ProfDrMedVet,MS,Diplomate ACVS,ECVS<sup>1</sup>

<sup>1</sup>Equine Department, Vetsuisse-Faculty Zurich, Switzerland, <sup>2</sup>ARTORG Center for Biomedical Engineering Research, University of Bern, Switzerland

## Introduction

Computer assisted surgery (CAS) has been used since the early 1990s for various orthopedic procedures.<sup>1,2</sup> CAS allows the surgeon to accurately implement the preoperative plan and to implant screws at the desired, preplanned location as well as at the correct angle relative to the fracture plane.<sup>3</sup> The most popular application fields in humans are spine surgery, hip and knee arthroplasty and orthopedic trauma surgery. It could be shown in spine surgery that pedicle screws could be inserted with higher accuracy using image-guided computer navigation than with conventional methods.<sup>4</sup> In total knee arthroplasty an improvement in both precision and accuracy in obtaining optimal knee alignment using CAS could be documented.<sup>5,6</sup>

Some studies reported on higher operation costs due to more expensive equipment and prolonged surgery time by equal or worse outcome than with conventional technique.<sup>7,8</sup> Positive responses to this surgical adjunct promising further development and fine tuning preponderate in the literature.<sup>2,4-6,9-11</sup>

Potential indications for CAS in equine surgery include fractures of the distal, middle and proximal phalanx, the distal and proximal sesamoid bones, and condylar fractures of MCIII and MTIII as well as subchondral cystic lesions of various bones.<sup>12</sup>

Two types of systems have been described: Active CAS-systems, which work with infrared illuminating diodes that are connected via cables to strober box, and passive systems, which recognize the bone and the instruments in the defined space via 3 to 4 reflecting marker balls mounted in different configurations on the C-arm, the key instruments as well as the bone to be treated.<sup>13</sup>

Fractures of the distal phalanx usually are the result of an acute trauma such as kicking at a fixed object or a misstep. Most often fast or excessive work induces these fractures.<sup>14,15</sup> Fractures of the distal phalanx occur in all breeds. In Thoroughbreds they are most often found on the lateral aspect of the left front foot and the medial aspect of the right foot in association with the counterclockwise direction of training and racing. The forelimb is more commonly involved than the hind limb, because forelimbs bear more weight. In all the other breeds, the fractures are evenly distributed among the limbs.<sup>14-17</sup> Non-articular fractures are distinguished from articular ones. Midsagittal fractures - dividing the bone into two equal parts - are rare and account for 3 to 4% of all distal phalanx fractures.<sup>15,16</sup>

A fracture of the distal phalanx usually results in acute, moderate to severe lameness, accentuated during turns. The affected horses show an increased digital pulse, warm hoof and pain when pressure is applied with hoof testers. Distal interphalangeal joint effusion may be palpable.<sup>17</sup>

Midsagittal fractures can be treated non-surgically or surgically. Internal fixation is recommended as treatment of choice.<sup>18</sup> Lag screw fixation provides temporary compression and stability and decreases the articular gap that persists with conservative therapy.<sup>19</sup> A prolonged convalescence in horses older than 3 years can be avoided by lag screw repair.<sup>20</sup> Further immobilization to limit hoof expansion is recommended with a rim- or bar shoe with side clips.<sup>15,16</sup> Potential complications include postoperative

infection of the surgical site with development of osteomyelitis, screw irritation and screw rejection.<sup>14</sup>

The partially encased joint within the hoof wall complicates the surgical access to the region preventing direct visualization of the bone or fracture during surgery. In conventional surgery the placement of a single screw across the fracture is relatively simple but requires fluoroscopic views or numerous intraoperative radiographs to determine the precise location of the screw position and to guide the placement.<sup>21</sup> The appropriate site for screw insertion is midway between the joint surface and the center of the semilunar canal. The desired direction of the screw is parallel to the joint surface and perpendicular to the long axis of the limb.<sup>18,19,22</sup>

The results obtained with the SurgiGATE 1.0 System used in previous studies in distal phalanx and distal sesamoid bone fractures in the horse showed a greater precision of screw length selection and placement compared to the conventional technique. In imaginary axial distal phalanx fractures, the CAS technique took 10-15 minutes longer than the conventional one. In the distal sesamoid bone there was no significant difference in surgical time between the two techniques.<sup>23-25</sup> It has to be taken in account that there is a learning curve in CAS, resulting in decreases of surgery time with increased experience.

The goal of this study was to determine the precision and the accuracy of insertion of two cortex screws into the distal phalanx to treat an imaginary midsagittal fracture, with the help of the newly developed VetGate CAS-System. The results would be compared with those gained with the SurgiGATE 1.0 System.

## **Materials and Methods**

### *Cadaveric Limbs*

Five fresh, frozen equine cadaveric limb pairs (n=10) without knowledge of origin, randomly collected at the Equine Hospital of the University of Zurich and the Equine Clinic Niederlenz from euthanized or slaughtered horses, void of disease in the foot region, were used. The limbs were disarticulated at the carpometacarpal and the tarsometatarsal joint respectively. Because of the difficulties by creating artificial midsagittal fractures, an imaginary fracture was assumed for all samples.

### *Technical Equipment*

The X-ray images were obtained by the isocentric C-arm Arcadis Orbic 3D (Siemens Healthcare, Erlangen, Germany). The object to be scanned is placed half way between the x-ray emitting and the -receiving poles of the system, which reduces the size of the object that can be scanned. This 3-dimensional imaging system takes 100 high quality 2D radiographs over a 190° orbital rotation within 60 seconds and calculates them into



256 separate slices that can be viewed in three orthogonal orientations (frontal-, sagittal-, and horizontal planes respectively) as well as a 3-D image. The data is then transferred to the VetGate System via a cable.

The VetGate CAS-System used in this study is a custom-made navigation system (ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland). The system works with a passive optic tracking system (Polaris Spectra, Northern Digital Inc., Waterloo, Ontario, Canada). The tracker emits infrared light. The light is reflected by retro-reflecting marker balls and picked up by two cameras of the tracking system. At least three marker balls (BrainLab, Feldkrich, Germany) arranged in a unique configuration relative to each other (angle and distance) are attached to the objects to be navigated, such as hoof, drill, drill sleeve, drill calibrator and C-arm. The SurgiGATE 1.0 worked with an active optic tracking system, where the instruments were tracked with infrared light emitting diodes. The drill sleeve was not navigated in this system.<sup>23-25</sup> This system is not available anymore and the remaining one is not professionally serviced any more.

The room position of every marker can be identified relative to the camera. The planning and navigation software is based on the Open Source Framework MARVIN<sup>26</sup>.

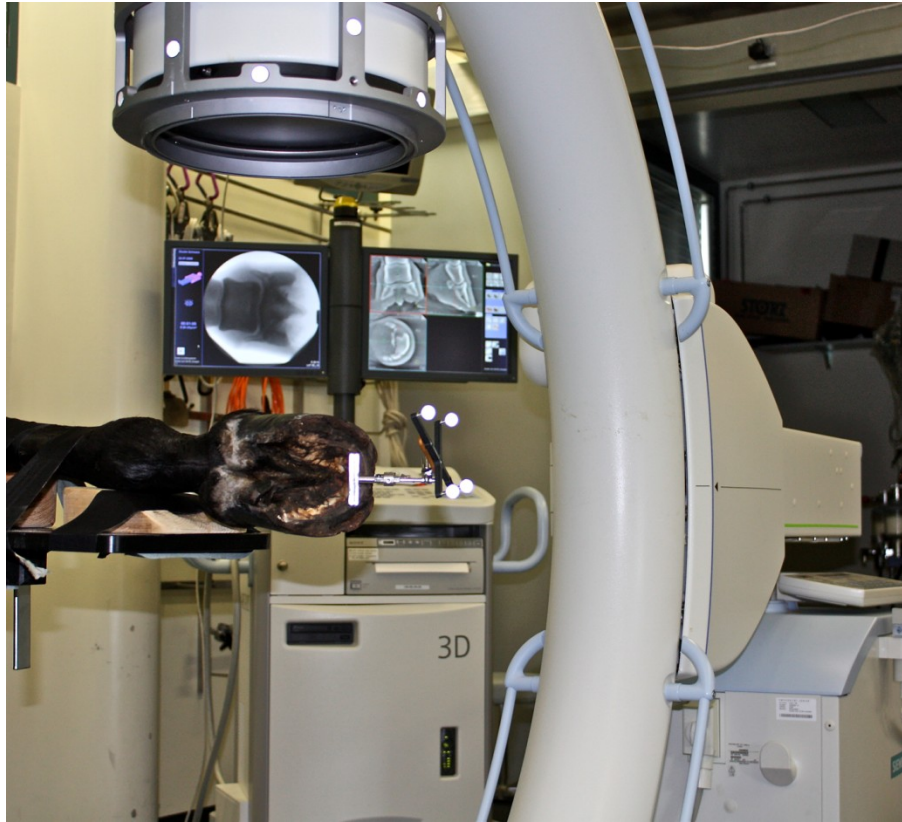
### *Surgical Procedure*

The frozen limbs were solidly fixed in lateral recumbency in a vice on an exchangeable carbon platform attached to the surgical table. The Dynamic Reference Base (DRB) with its marker-balls was attached with a specially designed clip (ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland) to the sagittal tip of the hoof capsule (Fig. 1).



**Figure 1.** Dynamic Reference Base (DRB) attached to the hoof tip

Two orthogonal fluoroscopic images were taken of the hoof-region to assure that the anatomic structures, such as distal phalanx were centered under the radiographic beam while the C-arm rotated around the bone to be treated. The pertinent data of the patient, or in this case the sample number, were entered into the system followed by scanning the hoof region (Fig. 2).

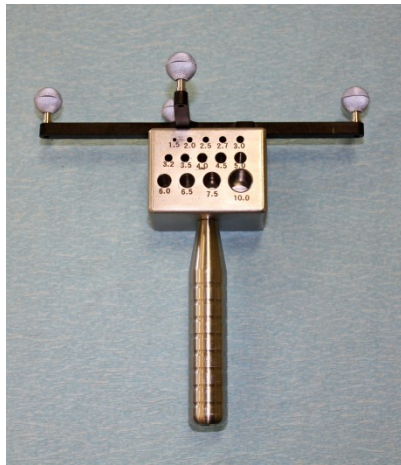


**Figure 2.** X-Ray scan with the isocentric C-arm Arcadis Orbic 3D

The acquired data were screened on the monitor and subsequently transferred to the navigation computer, where the hoof structures could be observed in three planes. The contrast of the distal phalanx could be adjusted in a stepless mode between bone-window and soft part-window.

In the planning mode of the navigation computer the ideal position in the bone was chosen on the displayed radiographic pictures in all three planes. The screw diameter was selected, the screw axis was chosen in the optimal location and subsequently the screw drawn along this axis. Final adjustments were made in screw orientation and – length before the coordinates were identified and saved. In this manner, as many screws as desired – for the present study two 4.5mm cortex screws were used for every distal phalanx – can be pre-planned. The screw identification number, its diameter and length were depicted in a window at the left side on the computer screen. Interference of two preplanned screws could be observed on the monitor

Once all screws were pre-planned and saved, the CAS-System was set to the navigation mode. The 4.5mm drill bit was attached to the power drill and its diameter and length verified with the help of the drill calibrator (ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland) (Figs. 3&4).

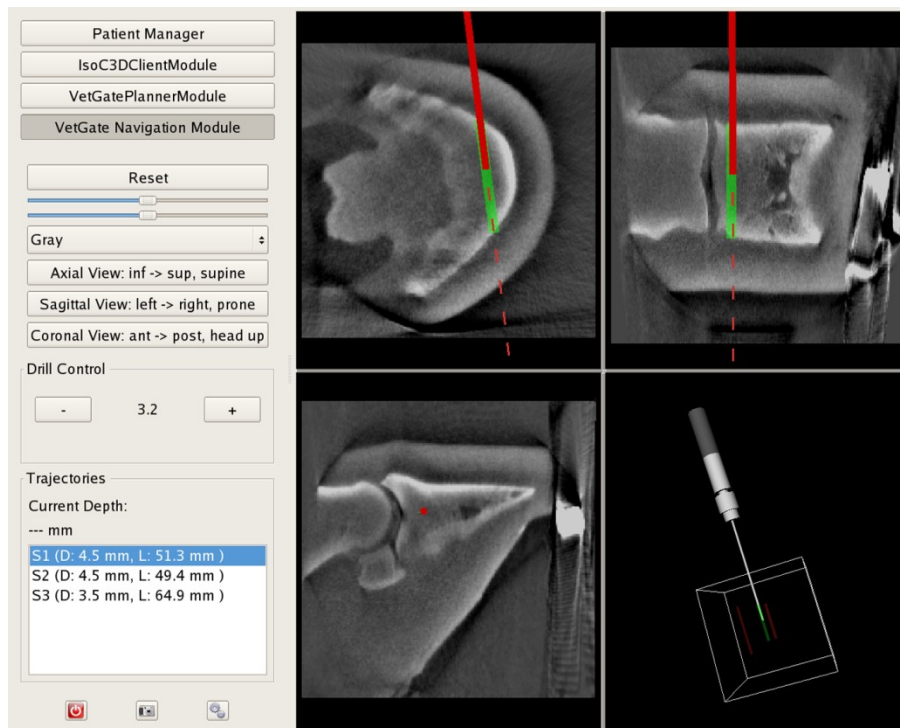


**Figure 3.** Drill diameter and length calibration-tool



**Figure 4.** Drill diameter and length calibration

The entry point and the drill bit direction were identified on the navigation screen and the glide hole for the screw prepared across the hoof wall (Fig. 5).



**Figure 5.** Screen shot in the Navigation Mode of the VetGate System during the drilling process of the gliding hole





**Figure 6.** Drilling the gliding hole

under constant surveillance and adjustment of the drill bit angles in two orthogonal planes on the computer screen. Once the drill bit reached the bone surface, the glide hole was continued to and minimally crossing the midsagittal plane (Fig. 6). The 4.5mm drill bit was removed and exchanged with the 3.2mm bit. After verification of the drill bit diameter and -length, the insert drill guide was placed into the glide hole and the thread hole was prepared across the remain of the distal phalanx. Once the drill bit reached the end of the bone, the exact screw length needed could be read off the navigation screen. The hole was subsequently tapped under navigation control. The hoof wall hole was subsequently axially enlarged with a 10mm diameter drill bit to facilitate countersinking the entry point of the screw into the bone and subsequent access of the screw head. A countersink depression was prepared manually to facilitate even distribution of the compressive forces around the perimeter of the screw-shaft junction followed by tapping of the thread hole to prepare the screw threads, which was conducted under constant observation of the monitor to assure tapping of the entire thread hole without penetrating the hoof wall.

The same procedure was repeated for the second screw hole.

Before screw insertion, 3-D imaging data acquisition with the Arcadis Orbic 3D was repeated to register the exact coordinates of the prepared hole axes within the bone.

These data were transferred again to the navigation system and in a later step the central longitudinal axes of holes were determined in the planning mode of the navigation system and the data stored to be compared with the data recorded prior to the preparation of the actual screw holes.

A screw length 2-3mm shorter than the one determined during preplanning was selected to account for the countersinking procedure. The selected cortex screw was inserted and solidly tightened. It should be noted that the depth gauge was not used to determine the length of the holes. Once selected, the screw was not changed anymore.

### *Macroscopic Evaluation*

All the bones were shelled out of their hoof capsule after soaking them twice for 4 hours in a 65-degree water bath. To void the isolated distal phalanges off their soft tissue remnants, they were again boiled twice for 3 hours in a water bath. Once clean the articular- and solar surface of each bone was closely examined for accidental traumatization by screw penetration and the entry- and exit points were evaluated for screw head seating and screw length respectively. The distance of the screw head and tip from the P3 surface were measured with a sliding caliper. Screws being within  $\pm 2\text{mm}$  in length at the tip were judged as being of correct length. Digital photographic images (Fig. 7) were taken from all bones from the top, the bottom and from both sides.



**Figure 7.** Isolated distal phalanx sample with the two inserted screws

In a next step the screws were removed and the distal phalanges transected in three parasagittal planes to determine accidental penetration of the semilunar canal.

## *Statistical Analyses*

The statistical analyses were performed by using commercial computer software (STATA). The optimal and actual screw lengths in the present study and the difference between optimal and computer determined screw length were compared to the data compiled in the study conducted by Andritzky et al with the SurgiGATE System.<sup>23</sup> The Student unpaired t-test was used for comparison of these data. To compare the Clinical Screw Length Assessment with the ones determined by Andritzky et al.<sup>23</sup> the Fisher's exact chi square-test was used. For all analyses, a P value <0.05 was considered significant.

## **Results**

In none of the specimens did screw penetration of the articular or solar surface or the semilunar canal occur (Tab. 1).

For the data of the 20 screws, a mean discrepancy of angulation angle of 1.93° (range, 0.25-4.04°) was calculated. Mean difference in screw entry point was 2.45mm (range, 0.85-4.18mm). The screw exit point had a mean difference of 3.02mm (range, 1.26-5.41mm).

For the 10 proximal screws (S1): a mean discrepancy of angulation angle of: 1.93° (range, 0.25-3.36°) was calculated. Mean difference in screw entry point was 2.27mm (range, 0.85-4.18mm); screw exit point 3.32mm (range, 1.81-4.95mm).

For the 10 distal screws (S2) a mean discrepancy of angulation angel of 1.92° (range, 0.81-4.04°) was calculated. Mean difference in screw entry point was 2.62mm (range, 1.57-3.76), screw exit point 2.73mm (range, 1.26-5.41mm).

The difference between optimal and actual screw length is significantly better in this study ( $p < 0.001$ ). There is no difference between optimal and computer determined screw length comparing the two studies ( $p = 0.5117$ ) (Tab. 2).

**Table 1.** Results of dissection and outcome of the surgery for the 10 distal phalanx samples

Case No.	Screw No.	Results of dissection					Outcome
		Damages			Screw insertion	Screw length	
		Articular surface	Solar surface	Canalis semilunaris			
1	S1	-	-	-	Ok	Ok	Perfect
	S2	-	-	-	Ok	Ok	Perfect
2	S1	-	-	-	Ok	Ok	Perfect
	S2	-	-	-	Ok	Ok	Perfect
3	S1	-	-	-	Ok	Ok	Perfect
	S2	-	-	-	Ok	Too short	Moderate
4	S1	-	-	-	Ok	Ok	Perfect
	S2	-	-	-	Ok	Ok	Perfect
5	S1	-	-	-	Ok	Ok	Perfect
	S2	-	-	-	Ok	Ok	Perfect
6	S1	-	-	-	Ok	Ok	Perfect
	S2	-	-	-	Ok	Ok	Perfect
7	S1	-	-	-	Ok	Too short	Moderate
	S2	-	-	-	Ok	Ok	Perfect
8	S1	-	-	-	Ok	Ok	Perfect
	S2	-	-	-	Ok	Ok	Perfect
9	S1	-	-	-	Ok	Too short	Moderate
	S2	-	-	-	Ok	Ok	Perfect
10	S1	-*	-	-	Ok	Too short	Moderate
	S2	-	-	-	Ok	Ok	Perfect

Abbreviations: S1: proximal screw, S2: distal screw, -: not affected by the screw \* Screw head to close to the joint surface but without penetration of the surface



**Table 2.** Difference between optimal, actual and computer determined screw length in two different studies

Study	Difference between optimal and actual screw length	Difference between optimal and computer determined screw length
A	1.40±1.47	2.50±2.14
B	3.00±3.16	2.82±2.27

Comparison (Mean ± SD in mm) of two Computer-Assisted Surgical Systems; *VetGate* (A) and *SurgiGATE* 1.0; Andritzky et al. (B)<sup>24</sup> for insertion of 2 screws across a simulated midsagittal third phalanx fracture.

Comparing the results from this study (A) with Andritzky et al. (B)<sup>23</sup> there is no statistical difference between this two studies ( $p=0.444$ ). Nevertheless a tendency towards improvement is noticeable (Tab. 3).

**Table 3.** Comparison of Clinical Screw Length Assessment

Study	Good% (number)	Bad% (number)
A ( <i>VetGate</i> )	100 (20)	0 (0)
B ( <i>SurgiGATE</i> 1.0) <sup>24</sup>	93.8 (15)	6.3 (1)

Screws were categorized as “good” (unlikely to cause pressure on the lamellae) or “poor” (likely to cause pressure on the lamellae).

## Discussion

Two very important improvements from the *SurgiGATE* 1.0 to the *VetGate* are the following:

- The LEDs are replaced with reflecting marker balls. In the previous system, the navigated instruments were connected to a strober box and subsequently to the navigation computer by cables. The mobility of the instruments was highly restricted and the different electrical cables were frequently entangled. Continuous movement of the instruments and their electrical cables made maintenance of sterility difficult. With the *VetGate* instruments this is not a problem anymore.
- The drill sleeve of the *VetGate* System is equipped with marker balls, which moves this navigation tool to the top of the bone to be treated. In doing so, bending of the drill bit proximal to the drill sleeve has a less erroneous effect on the drill orientation,

resulting in increased precision. Bending of the drill bits, especially the longer ones was a considerable problem in the SurgiGATE System. Using the navigated drill sleeve, the curve is more or less equalized and the precision increased.

The reflecting marker balls cannot be sterilized with steam. A gas sterilizer is necessary, which is a minor disadvantage that can be overcome. The cameras need unobstructed view to the marker balls. During surgery the balls at the drill and the drill sleeve need to be adjusted in their position. Furthermore the balls of the DRB and those of the drill sleeve must not overlap each other. If this occurs, navigation is faulty.

A general advantage of CAS is the reduction of radiation exposure for all the involved people. Neither CT-imaging nor fluoroscopy is necessary during the surgery. The radiation exposure is about 60-80% lesser without a preoperative CT-imaging.<sup>27</sup> In addition, the C-arm is not used any longer after the registration process, which further reduces the risk of contamination. A disadvantage is the increased duration of the surgical procedure and associated costs.<sup>7</sup> The increased precision of the implant placement more than compensates for prolonged surgery time and the increased costs.

The results of this study compared to ones of Andritzky et al.<sup>23</sup> are similar. A satisfactory outcome was achieved with both systems. The difference between optimal and actual screw length is significantly better in this study. But the error rate is high using a sliding caliper.

A total of 4 screws were determined as too short out of the 20. The perfect screw length in this study was determined as follows: the tip should reach the bone surface  $\pm 2\text{mm}$ . The fixation of a fracture is even with a slightly "too short" screws adequate. As an average, the thread hole is between 20 and 30mm long and provides adequate holding strength to solidly tighten a screw inserted in lag fashion. The missing 2mm in a "too short" screw are therefore not significant. To avoid pressure on the sensitive laminae a short screw is preferred over a screw that is too long. From a clinical point of view these 4 screws would be judged as perfect.

In a real case the total length of the hole is determined with the depth gauge after drilling countersinking has been performed. This facilitates selection of a screw of correct length. Dependent upon the diameter of the hole in the hoof wall it may not be possible to insert the depth gauge all the way to the bone, resulting in an imprecise depth measurement. In most cases screws that are too long are selected. Such discrepancy can be detected after screw insertion by taking a tangential radiographic view at the screw exit point. If the screw protrudes after solid tightening, a shorter screw is selected. This could have been done in this experiment. However we made the decision at the onset of the study that we wanted to test the accuracy of the navigation system in determining the screw length needed. The 2-3mm we deducted from the determined length to compensate for the countersinking. Also the screw lengths increase in length in 2mm steps. Therefore, when an uneven length measurement was recorded, we deducted 3mm, with even recording we deducted 2mm.

In a real case, the first drill used has to be exchanged after penetration of the hoof capsule. This reduces the contamination risk of surgical site by the drill bit, because the hoof capsule, even after meticulous aseptic preparation cannot be looked at as being sterile. We did not exchange the drill in this study, to save time and drill bits and mainly because we worked on cadaveric limbs.

## **Acknowledgement**

The authors thank Mike Hässig for statistical analysis; Urs Müller, Kathrin Süss, Bruno Gretzner and Paul Müller for their invaluable support during collection, dissection and evaluation of the limbs.

## **References**

1. DiGioia AM, Jaramaz B, Colgan BD: Computer assisted orthopedic surgery. Image guided and robotic assistive technologies. Clin Orthop Rel Res:8-16, 1998
2. Laine T, Schlenzka D, Makitalo K, et al: Improved accuracy of pedicle screw insertion with computer-assisted surgery. A prospective clinical trial of 30 patients. Spine 22:1254-1258, 1997
3. Auer JA: Computer assisted orthopedic surgery (CAOS) in equine fracture treatment. Proc Eur Coll Vet Surg 12:70, 2003
4. Laine T, Lund T, Ylikoski M, et al: Accuracy of pedicle screw insertion with and without computer assistance: a randomized controlled clinical study in 100 consecutive patients. Eur Spine J 9:235-240, 2000
5. Bathis H, Perlick L, Tingart M, et al: Alignment in total knee arthroplasty. A comparison of computer-assisted surgery with the conventional technique. J Bone Joint Surg Br 86:682-687, 2004
6. Sikorski JM, Blythe MC: Learning the vagaries of computer-assisted total knee replacement. J Bone Joint Surg Br 87:903-910, 2005
7. Callaghan JJ, Liu SS, Warth LC: Computer-assisted surgery: a wine before its time: in the affirmative. J Arthroplasty 21:27-28, 2006
8. Kim Y-H, Kim J-S, Choi Y, et al: Computer-Assisted Surgical Navigation Does Not Improve the Alignment and Orientation of the Components in Total Knee Arthroplasty. J Bone Joint Surg Am 91:14-19, 2009

9. Chotanaphuti T, Ongnamthip P, Teeraleekul K, et al: Comparative study between computer assisted-navigation and conventional technique in minimally invasive surgery total knee arthroplasty, prospective control study. *J Med Assoc Thai* 91:1382-1388, 2008
10. Easley M, Chuckpaiwong B, Cooperman N, et al: Computer-assisted surgery for subtalar arthrodesis. A study in cadavers. *J Bone Joint Surg Am* 90:1628-1636, 2008
11. Liebergall M, Ben-David D, Weil Y, et al: Computerized navigation for the internal fixation of femoral neck fractures. *J Bone Joint Surg Am* 88:1748-1754, 2006
12. Fischer AT, Hardy J, Léveillé R, Rijkenhuizen ABM, Auer JA: Minimally Invasive Surgical Techniques., in Auer JA, Stick JA (eds): *Equine Surgery* (ed 3). St. Louis, Saunders Elsevier, 2006, pp 161-172
13. Grützner PA, Hebecker A, Waelti H, et al: Klinische Studie zur registrierungsfreien 3D-Navigation mit dem mobilen C-Bogen SIREMOBIL Iso-C3D. *electromedica* 71:58-67, 2003
14. Dyson S: Fractures of the distal phalanx, in Mike W. Ross DSJ (ed): *Diagnosis and Management of Lameness in the horse*. WB Saunders Company, 2003, pp 318-321
15. Scott EA, McDole M, Shires MH: A review of third phalanx fractures in the horse: sixty-five cases. *J Am Vet Med Assoc* 174:1337-1343, 1979
16. Honnas CM, O'Brien TR, Linford RL: Distal phalanx fractures in horses: A survey of 274 horses with radiographic assessment of healing in 36 horses. *Vet Radiol* 29:98-107, 1988
17. Bertone A: Fractures of the distal phalanx in Nixon A (ed): *Equine Fracture Repair* (ed 1). Philadelphia, WB Saunders, 1996, pp 146-152
18. Fackelmann G: Screw Fixation of Sagittal Fractures of the third Phalanx in Horses. *Vet Med Small Anim Clin* 96:1317-1324, 1974
19. Fackelmann G: Distal Phalanx, in Fackelmann GE, Auer JA, Nunamaker DM (eds): *AO Principles of Equine Osteosynthesis*. Stuttgart Thieme, 2000, pp 115-124

20. Rose RJ, Taylor BJ, Bellenger CR: Internal fixation of fractures of the third phalanx in three horses. *Aust Vet J* 55:29-32, 1979
21. Young DR, Kobluk CN: Diseases of bone, in Kobluk CN, Ames TR, Geor IJ (eds): *The Horse: Diseases and Clinical Management*. Philadelphia, WB Saunders Co, 1995, pp 785-786
22. Honnas CM VJR, Schumacher J.: Diagnosis and treatment of articular fractures of the equine distal phalanx. *Vet Med* 87:1208-1214, 1992
23. Andritzky J, Rossol M, Lischer C, et al: Comparison of computer-assisted surgery with conventional technique for the treatment of axial distal phalanx fractures in horses: an in vitro study. *Vet Surg* 34:120-127, 2005
24. Gygax D, Lischer C, Auer JA: Computer-assisted surgery for screw insertion into the distal sesamoid bone in horses: an in vitro study. *Vet Surg* 35:626-633, 2006
25. Rossol M, Gygax D, Andritzky-Waas J, et al: Comparison of computer assisted surgery with conventional technique for treatment of abaxial distal phalanx fractures in horses: an in vitro study. *Vet Surg* 37:32-42, 2008
26. Rudolph T, Puls M, Anderegg C, et al: MARVIN: a medical research application framework based on open source software. *Comput Meth Prog Biomed*: 91, 2:165-174, 2008
27. Gebhard F, Arand M, Fleiter T, et al: Computer assistierte Chirurgie, Entwicklung und Perspektiven 2001. *Der Unfallchirurg* 104:782-788, 2001

**D. Introduction of 3.5mm and 4.5mm Cortex Screws into the Equine Distal Sesamoid Bone with the Help of the VetGate Computer Assisted Surgery System and Comparison of the Results with those Achieved with the SurgiGATE 1.0 System: An In Vitro Study**

**Cornelia S. Schwarz,** MedVet<sup>1</sup>, **Tobias Rudolph,** PhD<sup>2</sup>, **Joerg A. Auer** ProfDrMedVet,MS,Diplomate ACVS&ECVS<sup>1</sup>, **Jens H. Kowal,** ProfDr<sup>2</sup>

<sup>1</sup>Equine Department, Vetsuisse-Faculty Zurich, Zurich, Switzerland, <sup>2</sup>ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland

## Introduction

Fractures of the distal sesamoid (navicular) bone are rare causes of lameness in the horse. The forelimbs are more commonly affected. The lameness is acute in onset and severe (3 - 4 / 5). There is increased sensitivity to hoof testers placed over the heel and central frog regions, especially in acute cases. The diagnosis is confirmed by means of diagnostic imaging techniques, most frequently radiography.<sup>1,2</sup>

Four different fracture types are distinguished: avulsion fractures of the distal or proximal margin, simple sagittal and parasagittal fractures of the body, multifragment fractures, and fractures along the frontal plane of the bone. Avulsion fractures are often associated with navicular disease. Therefore, these fractures are considered being part of an osteoarthritic syndrome.<sup>3</sup>

The simple vertical or slightly oblique fracture line running in a parasagittal plane, abaxial to the central ridge is the most common manifestation of distal sesamoid bone fractures diagnosed. These fractures occur by abrupt uneven pressures exerted upon the bone by the proximal and middle phalanx in concert with pressures applied by the deep digital flexor tendon.<sup>1,4</sup> The event responsible for the traumatic insult is often racing and training respectively, occasionally slipping and falling.<sup>5</sup> A kick hitting a solid object may also cause these fractures. Chronic aseptic podotrochlosis can predispose distal sesamoid bone fractures because of an increased bone mass loss.<sup>1</sup> Through the tight attachments of the collateral sesamoidean and the distal sesamoidean ligaments, the distal sesamoid bone is comparatively immobile. A distraction of fragments does not occur to any great extent, but there is some movement encountered at every step the horse makes. A fracture line is usually visible on the radiographs.<sup>4</sup>

Fractures must be differentiated from congenital separation, resulting in bipartite or tripartite distal sesamoid bones. They occur usually in more than one limb, but the fragment shapes may differ in number and size. One constantly encountered feature is the smooth and rounded edges of the fragments.<sup>2</sup>

Non-surgical therapy involves application of elevated heel-shoes and quarter clips to reduce hoof expansion and excessive pressure onto the bone. Initially the patients are kept in a stall. These fractures have a poor prognosis for entering an athletic career or return to it because healing occurs usually by a fibrous union. The failure of bony union is probably caused by continuous instability and micro movement of the fracture fragments. Even after several months of stall rest, slight to moderate lameness persists and a palmar (plantar) digital neurectomy may turn out to be the only option to relieve signs of pain associated with the fracture. Occasionally, adhesions between the deep digital flexor tendon and the fracture region develop. Radiographically the fracture line persists for up to many years. The typical features of a delayed union are apparent within several months.<sup>1,4,5</sup> Prolonged confinement of the hoof with side clips or a cast inhibits foot expansion during loading and eventually leads to a contracted foot, which may lead to alternate problems.

Insertion of a single cortex screw in lag fashion along the transverse axis results in intrafragmentary compression, which may lead to complete fracture healing in some horses. Screw insertion using conventional surgical technique demands extensive

radiographic or fluoroscopic monitoring and a specially developed drill guide.<sup>6,7</sup> Computer Assisted Surgery (CAS) has been reported to increase surgical precision.<sup>8-10</sup> However, the system used by Gygax et al. had several shortcomings that had to be solved.<sup>11</sup>

To the goals of this study were:

1. to evaluate the practicality of the newly developed VetGate CAS-System for the implantation of 3.5mm and 4.5mm cortex screws along the long axis of *in situ* cadaveric distal sesamoid bones with an imaginary midsagittal distal sesamoid bone fracture;
2. to determine the differences between the definition of the pre-planned screw axis and the axis of actually inserted screw; and
3. to compare the results reported earlier with SurgiGATE 1.0 System with those achieved with the VetGate CAS-System.

## **Materials and Methods**

### *Cadaveric Limbs*

Ten fresh, frozen equine cadaveric limb pairs (n=20) without knowledge of origin, randomly collected at the Equine Hospital of the University of Zurich and the Equine Clinic Niederlenz from euthanatized or slaughtered horses. The limbs were disarticulated at the carpo-metacarpal and the tarso-metatarsal joint respectively. An imaginary midsagittal fracture was assumed for all samples.

### *Technical Equipment*

The routine instruments for screw insertion in lag fashion were used in this study (Synthes GmbH, Solothurn, Switzerland). The isocentric C-arm Arcadis Orbic 3D (Siemens Healthcare, Erlangen, Germany) was used for collecting the diagnostic image studies. The VetGate CAS-System used in this study is a custom-made navigation system (ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland). The system works with a passive optic tracking system (Polaris Spectra, Northern Digital Inc., Waterloo, Ontario, Canada). At least three marker balls (BrainLab, Feldkrich, Germany) are attached to the objects to be navigated, such as hoof, drill, drill sleeve, drill calibrator and C-arm. The planning and navigation software is based on the Open Source Framework MARVIN<sup>12</sup>.

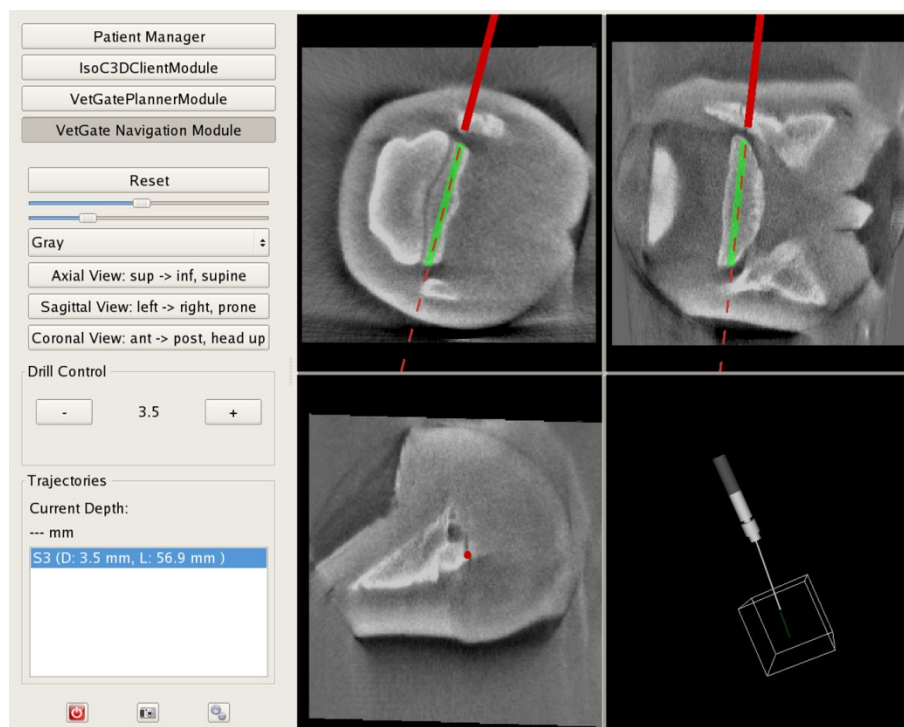


## *Surgical Procedure*

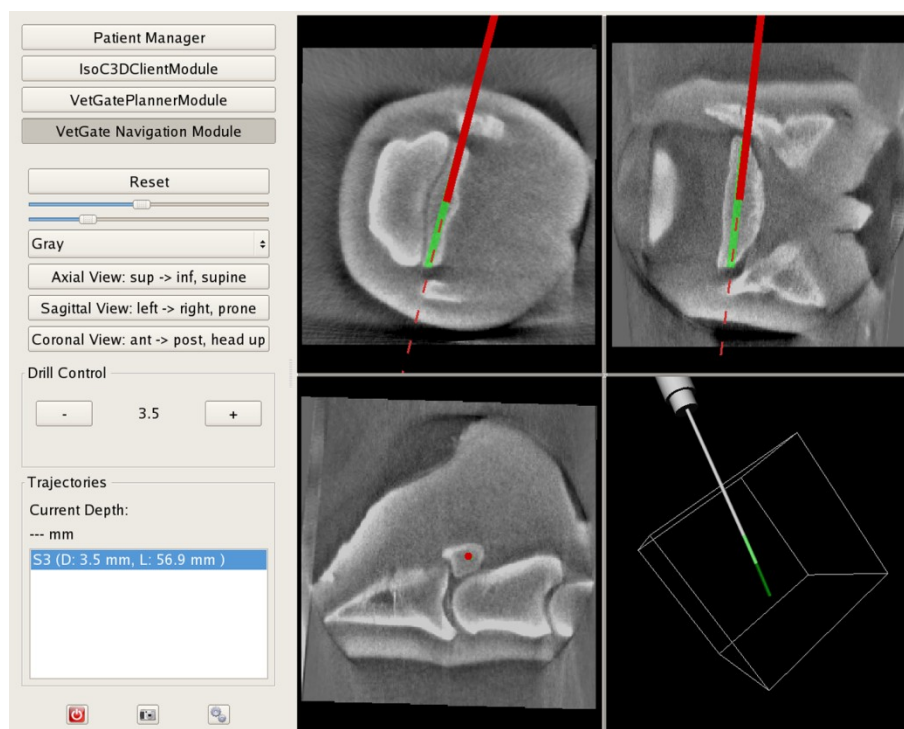
The two limbs of each pair were randomly assigned to two groups: One to the group where a 4.5mm cortex screw was implanted into the distal sesamoid bone and the other to the group where a 3.5mm cortex screw was inserted.

The frozen limbs were solidly fixed in lateral recumbency in a vice on an exchangeable carbon platform attached to the surgical table. The Dynamic Reference Base (DRB) with its marker-balls was attached with a specially designed clip (ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland) to the sagittal tip of the hoof capsule. Two orthogonal fluoroscopic images were taken of the hoof-region to assure that the anatomic structure of interest was centered under the radiographic beam while the C-arm rotated around the bone to be treated. The pertinent data of the patient, or in this case the sample number, were entered into the system followed by scanning the hoof region. The acquired data were shown on the monitor and subsequently transferred to the navigation computer, where the hoof structures could be observed in three planes. The contrast of the distal sesamoid bone could be adjusted in a stepless mode between bone-window and soft part-window.

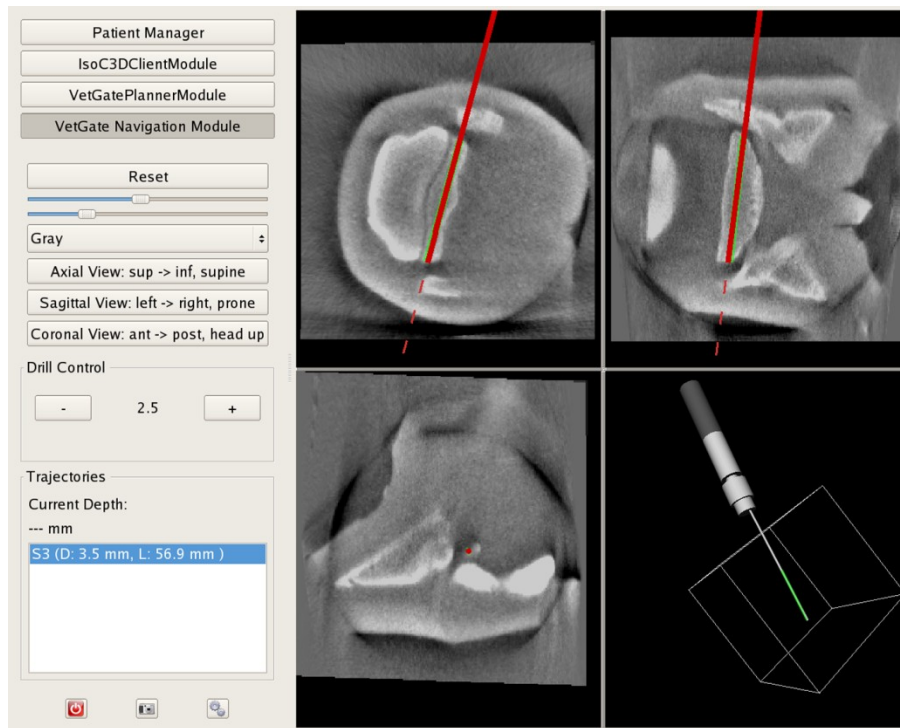
In the planning mode of the navigation computer the ideal position in the bone was chosen on the displayed radiographic pictures in all three planes. The screw diameter was selected, the screw axis was chosen in the optimal location and subsequently the screw drawn along this axis. Final adjustments were made in screw orientation and -length before the coordinates were identified and saved. The screw identification number, its diameter and length were depicted in a window at the left side on the computer screen. Once the screw was pre-planned and saved, the CAS-System was set to the navigation mode. The 3.5mm drill bit was attached to the power drill and its diameter and length verified with the help of the drill calibrator (ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland). The entry point and the drill bit direction were identified on the navigation screen and the glide hole for the screw prepared across the hoof wall under constant surveillance and adjustment of the drill bit angles in two orthogonal planes on the computer screen. A hole across the hoof wall, the collateral cartilage as well as the glide hole up to the imaginary fracture line in the sagittal plane of the distal sesamoid bone was prepared. (Figs. 1&2). The insert drill guide was inserted across the hoof wall, collateral cartilage and into the glide hole within the distal sesamoid bone. This allowed concentric drilling of the thread hole with a 2.5mm drill across the remaining half of the bone (Fig. 3). To facilitate access of the countersink, the hole across the hoof wall was enlarged with the help of an 8mm drill bit down to bone surface. At that point of the study the initial imaging collection - with the DRB still in the bone - was repeated to document the location of the screw hole within the bone. At a later stage the central axis of the hole was drawn on the computer screen and saved for comparison with the pre-planned screw axis.



**Figure 1.** Start of the drilling process with a 3.5mm drill



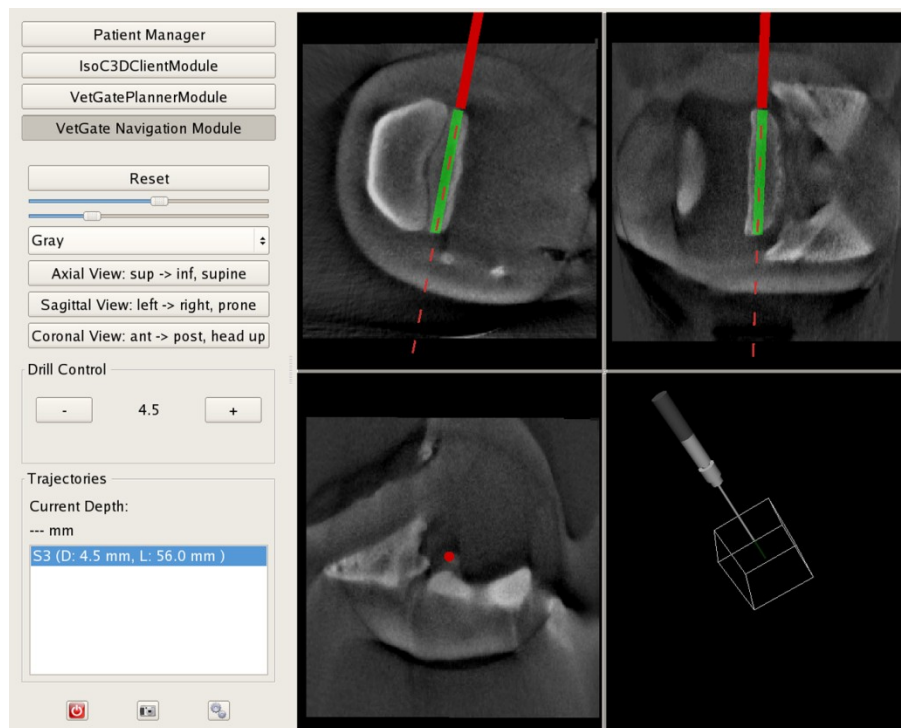
**Figure 2.** Drilling of the glide hole, 3.5mm hole up to the imaginary fracture line in the sagittal plane of the distal sesamoid bone



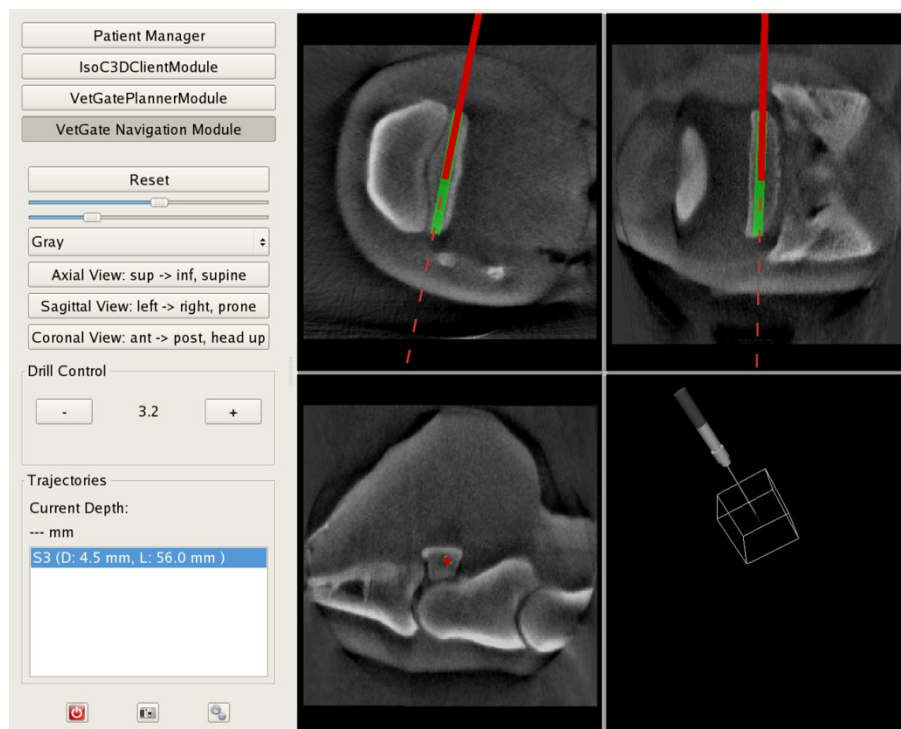
**Figure 3.** Concentric drilling of the thread hole with a 2.5mm drill across the remaining half of the bone

The screw length was determined by subtracting 2-3mm (allowance for countersinking) from the length determined on the computer screen during the preplanning phase. After countersinking the near cortex of the distal sesamoid bone and preparation of the screw threads along the thread hole, the screw of predetermined length was inserted and solidly tightened. By study design, the depth gauge was not used to determine the exact length of the prepared hole in the distal sesamoid bone.

The same procedure was repeated for the 4.5mm cortex screw (Figs. 4 & 5).



**Figure 4.** Drilling procedure with the 4.5mm drill



**Figure 5.** Drilling procedure with the 4.5mm drill

## *Evaluation*

The distal sesamoid bones were removed after opening the coffin joint and transecting the ligamentous attachments. The bones were boiled for 4 hours to facilitate removal of soft tissue remnants. Once removed the articular- and flexor surfaces and the distal and proximal margin of each bone were closely examined for accidental screw penetration. The tolerance for the screw tip at the exit point was set at  $\pm 2\text{mm}$ . Protruding screw tips were measured with a sliding caliper.

Digital photographic images were taken from all bones from all sides. The macroscopic outcome was classified as perfect, moderate and poor using the following criteria: length of the screw, head of the screw, and position of the screw.

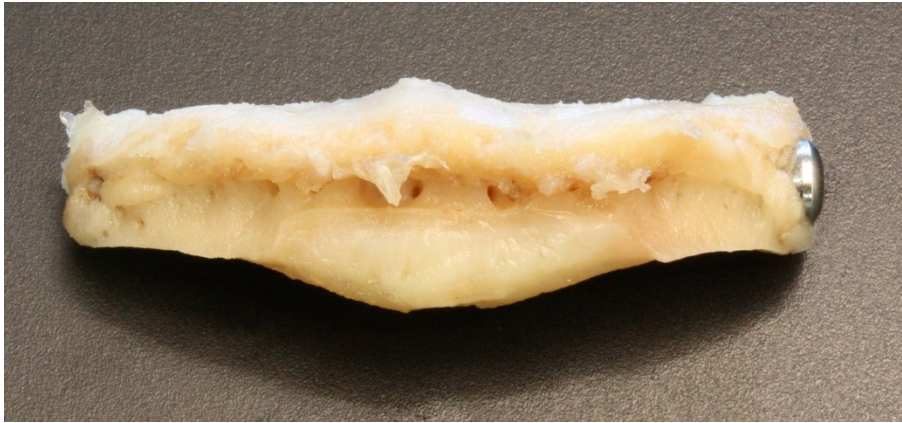
## *Statistical Analyses*

The statistical analyses were performed by using commercial computer software (STATA). To compare the axis angles, entry and exit point of the 3.5 and 4.5mm screws, the Student t-test was used. To compare the outcome of this study with the one of Gygax et al.<sup>11</sup> and to compare the outcome of 3.5mm versus 4.5mm screws, the Fisher's exact chi-test was used. For all analyses, a P value  $< 0.05$  was considered significant.

## **Results**

1. The handling and the implantation of the screws with the VetGate CAS-System is straight forward. Operating of the computer is done step by step. No special computer knowledge is necessary. Accidental loosening or removal of the Dynamic Reference Base (DRB) from the hoof must be avoided because this would necessitate starting the entire procedure over from the beginning. During the drilling process the marker balls must not overlap each other.

Inspection of the dissected distal sesamoid bones revealed a perfect position of all 3.5mm screws (Fig. 6, Tab. 1a). For the 4.5mm screws, in 1 case a perfect, in 1 case a moderate and in 8 cases a poor position was found (Tab. 1b). In the poor cases, the screw position within the bone was in all samples perfect, but the screw head damaged the articular surface because of its width (8mm diameter) (Fig. 7).



**Figure 6.** Dissected distal sesamoid bone: perfect position of the 3.5mm screws



**Figure 7.** Dissected distal sesamoid bone: perfect position of the 4.5mm screw but damage of the articular surface by the screw head



**Table 1a.** Results of the macroscopic evaluation of the 3.5mm screws

Case No.	Results of dissection					Outcome
	Damage to surface of distal sesamoid bone					
	Articular	Flexor	Distal rim	Proximal rim	Screw insertion	
1	-	-	-	-	Ok	Perfect
4	-	-	-	-	Ok	Perfect
6	-	-	-	-	Ok	Perfect
8	-	-	-	-	Ok	Perfect
10	-	-	-	-	Ok	Perfect
12	-	-	-	-	Ok	Perfect
14	-	-	-	-	Ok	Perfect
16	-	-	-	-	Ok	Perfect
18	-	-	-	-	Ok	Perfect
20	-	-	-	-	Ok	Perfect

**Table 1b.** Results of the macroscopic evaluation of the 4.5mm screws

Case No.	Results of dissection					Outcome
	Damage to surface of distal sesamoid bone					
	Articular	Flexor	Distal rim	Proximal rim		Screw insertion
2	+	-	-	-	Ok	Moderate
3	++	-	-	-	Ok	Poor
5	-	-	-	-	Ok	Perfect
7	++	-	-	-	Too long	Poor
9*	++	-	-	-	Too long	Poor
11	++	-	-	-	Ok	Poor
13	++	-	-	-	Ok	Poor
15	++	-	-	-	Ok	Poor
17	++	-	-	-	Ok	Poor
19	++	-	-	-	Ok	Poor

Abbreviations: + slightly affected by the screw, ++ plainly affected by the screw or screw head, - not affected by the screw

9\*: The screw is located deeper in the bone because the articular surface is damaged. Because the hole length was not directly measured after drilling, the screw is too long.

2. For the data of the 10 3.5mm screws, a mean discrepancy of angulation angle of  $1.11^{\circ}$  (range,  $0.12-2.13^{\circ}$ ) was calculated. Mean difference in screw entry point was 2.35mm (range, 1.41-3.44mm). The screw exit point had a mean difference of 2.11mm (range, 0.73-3.43mm).

For the 10 specimens with the 4.5mm screws, a mean discrepancy of angulation angle of  $2.09^{\circ}$  (range,  $0.07-4.38^{\circ}$ ) was calculated. Mean difference in screw entry point was 2.49mm (range, 1.06-4.13mm). The screw exit point had a mean difference of 2.94mm (range, 1.52-4.27mm).

Statistically there is no significant difference between angles of the 3.5mm and 4.5mm screws ( $p=0.07$ ), entry ( $p=0.7299$ ) nor exit point ( $p=0.0932$ ).

Comparing the outcome (Tab. 1a&b), the 3.5mm screws are significantly better than the 4.5mm screws ( $p<0.001$ ).

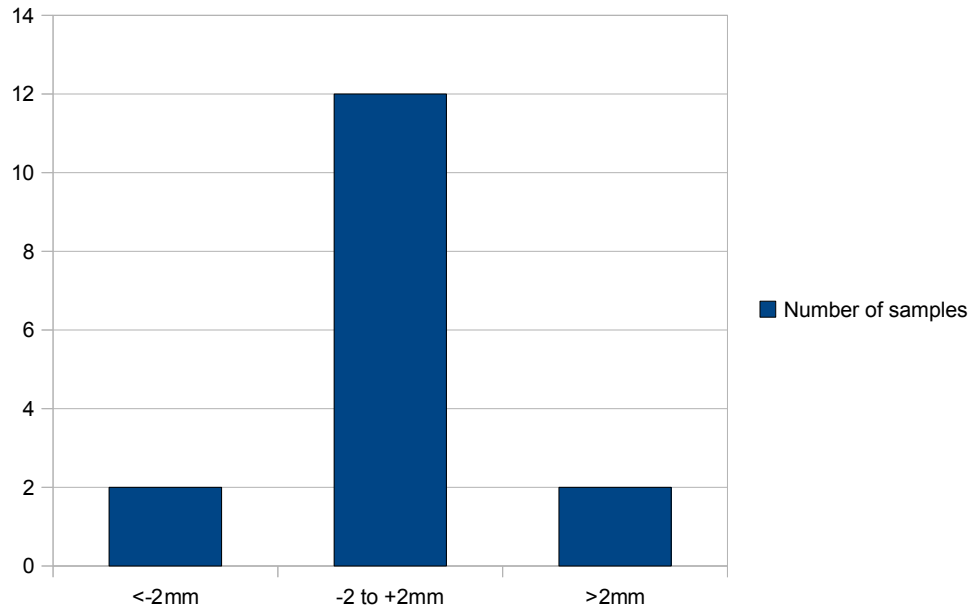
The postoperatively measured hole length was used as optimal screw length. The absolute aberrance from this length to the protruding and the too short screws is 1.77mm (range -5.8 to 3.6mm) (Tab. 2). Fig. 8 shows the distribution of aberrance from the chosen screw length to the optimal screw length (the postoperative measured hole length respectively).



**Table 2.** Actual screw length versus postoperative measured hole length (in mm)

No.	Actual screw length	Postoperative measured hole length	Difference
1	55 (58)	58.8	-3.8 (-0.8)
2	58	55.8	2.0
3	52	51.7	0.3
4	50 (52)	57.8	-7.8 (-5.8)
5	62	65.7	-3.7
6	65 (62)	64.2	0.8 (-2.2)
7	56	52.6	3.4
8	55 (54)	51.6	3.4 (2.4)
9	52	48.4	3.6
10	50	50	0
11	52	53.4	-1.4
12	55	55.3	-0.3
13	50	50.8	-0.8
14	50	50.9	-0.9
15	52	51.8	0.2
16	50 (52)	51.7	-1.7 (-0.3)
17	54	55.6	-1.6
18	55	56.3	-1.3
19	54	57.9	-3.9
20	50	50.4	-0.4

Comments: The numbers in brackets correspond to the desired but not available screw length. “-“ refers to the screw being too short.



**Figure 8.** Distribution of aberration of the screw length to the perfect hole length from all samples (n=20)

**3.** The results of this study with the 3.5mm screws, compared to the 3.5mm CAS screws of Gyga et al.<sup>11</sup>, are significantly better ( $p=0.023$ ) (Tab. 3).

**Table 3.** Comparison of screw placement with the VetGate (3.5mm and 4.5mm) and SurgiGATE 1.0 system (3.5mm).<sup>11</sup>

	VetGate 3.5mm	VetGate 4.5mm	SurgiGATE 3.5mm
Perfect	10	1	4
Moderate	0	1	3
Poor	0	8	1

## Discussion

In this study slightly frozen limbs were used. If treating a distal sesamoid bone fracture of a living horse, the distal sesamoid bone must be fixed by applying dorsiextension of the hoof and maintaining during the surgical procedure. This places the flexor tendons under tension and fixes the distal sesamoid bone between the deep digital flexor tendon and the distal phalanx.

The differences in the axis angle of the 4.5mm screws ( $2.09^\circ$ ) and the 3.5mm screws ( $1.11^\circ$ ) can only be explained by human error. A greater range could have been tolerated in the smaller screws because the ratio between screw diameter and bone diameter is larger than with the 4.5mm screws. This is in particular the case in dorsopalmar/dorsoplantar direction. Nevertheless this does not explain the small axis angle difference in the 3.5mm group. The error probability in the calculation of this parameter is high. The axes of the actually implanted screws were drawn in after the screw hole was drilled. It is easily possible that a slight aberrance occurred at this time.

The results with the 4.5mm screws are poor. Only one of the 10 specimens had a perfect outcome. In one specimen, the articular surface was slightly affected; the screw head deformed the cartilage minimally. In the rest of the specimens, the screw head damaged the articular surface. The location of the screw within the bone was in all specimens correct. The screw head with its 8mm diameter is too wide for the distal sesamoid bones. The head overlapped the articular rim and damaged the articular surface. The reason for the perfect and the moderate outcome in 2 of the 10 specimens with a 4.5mm screw can probably be found in the bone size. In specimen 2 a bone width of 20mm was measured with a sliding caliper at the widest part of the bone (the middle), whereas in specimen 5 19mm were measured. All other bones were thinner. The average width of all samples was 16.2mm with a range from 14 to 20mm (14-17mm in the other 8 bones). In the 3.5mm screw group, no problems with the screw head size were encountered.

Therefore the standard 4.5mm cortex screws are not applicable in Thoroughbred or Warmblood horses of average size. However a 4.5mm cortex screw with a smaller head diameter (6mm) may turn out to be the ideal implant for fixation of distal sesamoid bone fractures. Further studies on that aspect are needed.

Possible reasons for the significantly better outcome in this study compared to Gyax et al.<sup>11</sup> were discussed in Schwarz et al. (2010).<sup>13</sup>

The 3.5mm screws are not available in all desired lengths. From 50mm onward the screw size increases in 5mm increments instead of 2mm steps. Hence in 5 cases the desired screw length was not available and a shorter one had to be selected in 3 cases (1, 4, 16) and a longer one in 2 cases (6, 8).

In none of the specimens did the screw tips protrude more than 2mm. It is not possible to determine the exact screw length needed with the help of the slide caliper or

postoperative x-rays. This aberration is noticeable in the comparison of actual screw length and postoperative hole length. Furthermore, determination of the actual depth of countersinking is impossible. For the authors the inspection of the bones clinically with the help of diagnostic imaging procedures is the most important factor and considering the results achieved with the 3.5mm treatment of distal sesamoid bone fractures with this implant are more than satisfying.

## **Acknowledgement**

The authors thank Mike Hässig for statistical analysis; Urs Müller, Kathrin Süss, Bruno Gretzner and Paul Müller for their invaluable support during collection, dissection and evaluation of the limbs.

## **References**

1. Wintzer HJ, Daemrich K: [On navicular bone fractures of the horse]. Schweiz Arch Tierheilkd 109:487-496, 1967
2. Reeves MJ, Yovich JV, Turner AS: Miscellaneous conditions of the equine foot. Vet Clin North Am Equine Pract 5:221-242, 1989
3. Fürst AE, Lischer CJ: The Foot, in: Auer JA, Stick JA (eds): Equine Surgery (ed 3). St. Louis, MO: Saunders Elsevier, 2006, pp 1184-1217
4. Wyn-Jones G: Fractures of the equine navicular bone. Vet Ann 25:201-210, 1985
5. Lillich JD, Ruggles AJ, Gabel AA, et al: Fracture of the distal sesamoid bone in horses: 17 cases (1982-1992). J Am Vet Med Assoc 207:924-927, 1995
6. Nemeth F, Dik KJ: Lag screw fixation of sagittal navicular bone fractures in five horses. Equine Vet J 17:137-139, 1985
7. Auer JA: Principles of fracture treatment, in Auer JA, Stick JA (eds): Equine Surgery. St. Louis, MO: Saunders Elsevier, 2006, pp 1000-1029
8. Laine T, Lund T, Ylikoski M, et al: Accuracy of pedicle screw insertion with and without computer assistance: a randomised controlled clinical study in 100 consecutive patients. Eur Spine J 9:235-240, 2000

9. Bathis H, Perlick L, Tingart M, et al: Alignment in total knee arthroplasty. A comparison of computer-assisted surgery with the conventional technique. J Bone Joint Surg Br 86:682-687, 2004
10. Sikorski JM, Blythe MC: Learning the vagaries of computer-assisted total knee replacement. J Bone Joint Surg Br 87:903-910, 2005
11. Gygax D, Lischer C, Auer JA: Computer-assisted surgery for screw insertion into the distal sesamoid bone in horses: an in vitro study. Vet Surg 35:626-633, 2006
12. Rudolph T, Puls M, Anderegg C, et al: MARVIN: a medical research application framework based on open source software. Comput Meth Prog Biomed: 91, 2:165-174, 2008
13. Schwarz CS, Rudolph T, Auer JA, et al: Comparison of the VetGate and SurgiGATE 1.0 Computer Assisted Surgery Systems for Insertion of Cortex Screws across the Distal Phalanx in Horses; An In Vitro Study, Submitted to Vet Surg

## **E. Acknowledgement**

Gerne danke ich an dieser Stelle all jenen Personen, welche mir die Erarbeitung der vorliegenden Dissertation ermöglicht und mich dabei unterstützt haben.

Ein grosser Dank gilt hierbei allen voran Jörg Auer, für seine einmalige Unterstützung und die hervorragende Betreuung während des Verfassens der Arbeit.

Ebenfalls danke ich Tobias Rudolph für die angenehme Zusammenarbeit und seine Hilfestellung. Die Arbeit mit dem VetGate CAS-System ist grossartig.

Weiter bedanke ich mich herzlichst bei Paul Müller und Bruno Gretzner für die Beschaffung der für meine Untersuchungen notwendigen Pferdebeine, bei Kathrin Süss und Urs Müller für die geduldige Unterstützung bei der Präparation der Proben und bei Mike Hässig, der mich kompetent durch die Dunkelheit der Statistik geführt hat.

Ein besonderer Dank gilt aber auch meiner Familie und meinen Freunden, die mich stets unterstützt und begleitet haben und trotz meiner unmöglichen Arbeitszeiten immer und immer wieder Verständnis für mich und meine Tätigkeit aufbringen konnten.

## **F. Curriculum Vitae**

Name	Cornelia Sibylle Schwarz
Geburtsdatum	26.02.1984
Geburtsort	Zürich
Nationalität	Schweiz
Heimatort	Schaffhausen und Winterthur

1991-1997	Primarschule Hombrechtikon
1997-2003	Kantonsschule Zürcher Oberland, Wetzikon
2001-2002	Liceo UNESCO, San Isidro, Pérez Zeledón, Costa Rica
2003	Mittelschulabschluss, Maturität mit Schwerpunkt Spanisch

2003-2008	Studium der Veterinärmedizin an der Universität Zürich, Schweiz
Oktober 2008	Staatsexamen an der Universität Zürich, Schweiz

2009-2010	Assistenzstelle Pferdeklinik Neugraben AG, Niederlenz, Schweiz
Seit 7.2010	Internship Kleintierchirurgie an der Vetsuisse-Fakultät Zürich, Schweiz

Zürich, August 2010